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Assessing the Growth and Yield of Green Gram (*Vigna radiata* L.) under Sodic Soil through Soil Amendments and Foliar Nutrition

R. Mohanapriya[1]*, R. Kalpana[2], A. Alagesan[3], K. Vijay Aravinth[4], M. Guna[1] and M. Silambarasan[1]

[1]*Division of Agronomy, School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore, T.N., India*
[2]*Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, T.N., India*
[3]*Department of Agronomy, Agricultural College and Research Institute, Nagapattinam, T.N., India*
[4]*Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, T.N., India*

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ABSTRACT

Among pulses green gram is most suitable crop for barren land cultivation and is grown all over India. But production and productivity of crop was very low in salt affected soils due to the presence of high levels of salt accumulation in cation exchange complexes. Under these circumstances, application of soil amendments and foliar nutrition is one of the important agricultural practices that can be used in integrated nutrient management approach. To enhance the productivity under sodic soil condition, a field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli during summer 2022 to study the effect of soil amendments and foliar nutrition on growth, physiological parameters, soil enzymes, NPK uptake and yield of green gram. The experiment was laid out in split plot design with three replications. The treatments comprised of different soil amendments in main plots and three foliar spray combinations in sub plots. The results showed that, Gypsum @ 50 % GR + Press mud @ 10 t ha^{-1}+ FS of Brassinosteroid 0.2 ppm @ 30 DAS registered significantly higher of mean values dry matter production (3425 kg ha^{-1}), root nodules $plant^{-1}$(12.75 at 45 DAS), SPAD value (30.25), leaf area index (3.87), crop growth rate (9.39 g m^{-2} d^{-1}) at 45-65 DAS. The same combination recorded higher NPK uptake by crop, grain and haulm yield (1110 & 2175 kg ha^{-1}) with lower proline content (1.15µg g^{-1}) over farmers practices (FP). However, Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of Brassinosteroid 0.2 ppm @ 30 DAS produced on par yield.

Key words: *Foliar nutrition, Green gram, Growth, Sodicity, Soil amendments, Yield.*

Introduction

Green gram *(Vigna radiata* (L) is a tropical grain legume originated from India and commonly grown in South and Southeast Asia's subtropical regions. In India, about 6.72 million ha, which is around 2.1 % of the country's geographical area is salt affected of which 3.77 million ha is sodic. Total sodic soil area in Tamil Nadu is around 0.35 million ha, accounting for 9.4% of total sodic soil area in India (Kumar and Sharma, 2020). Salt stress causes a significant reduction in green gram development. Sodicity is characterized by high pH (>8.2) and high ESP (>15) with EC typically 4 dSm^{-1} leading to low biological activity, poor physical characteristics and nutrient deficiencies.

There is an urgent need to prevent further land degradation and restore the fertility of degraded soils since the continual increase in salinization on a global scale makes saline-sodic soils the most prominent category of degraded soils with severe consequences on agriculture production. Organic amendments are substances that can ameliorate soil physical, chemical and biological properties, promote plant nutrition and can mitigate the adverse impacts of soil salinity and sodicity (Abbott *et al.,* 2018). Besides, foliar application is credited with the advantage of quick and efficient utilization of nutrients, elimination of losses through leaching and fixation and regulating the uptake of nutrient by plants (Manonmani and Srimathi, 2009). Foliar feeding is often the most effective and economical way to improve plant nutrient deficiency in green gram under stress condition (Dixit *et al.,* 2008) and (Thirumeninathan *et al.,* 2017). The aim of this work was to evaluate the potential effects of organic amendment and foliar nutrition on soil chemical properties, crop growth, development and nutrient availability in sodic soil condition.

Materials and Methods

Experimental site

The field experiment was conducted during summer season of 2022 at field No. A_2c at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli situated at Manikandam Block of Tamil Nadu.

Treatment details

The field trial was laid out in split plot design with three replications. The treatments comprised of soil amendments (SA) *viz.,* M_1-*Pongamia* GLM @ 6.25 t ha^{-1}, M_2- Pressmud @ 10 t ha^{-1}, M_3-CSR GROMOR @ 25 kg ha^{-1}, M_4-Gypsum @ 50 % GR, M_5-Gypsum @ 50 % GR + *Pongamia* GLM @ 6.25 t ha^{-1}, M_6-Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}, M_7-Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} and M_8-Farmers practice (FP), respectively in main plots and foliar nutrition (FN) in sub plots *viz.,* S_1-Foliar spray (FS) of CSR GROMOR @ 3% @ 30 DAS, S_2-Foliar spray (FS) of Brassinosteroid (BRs) 0.2 ppm @ 30 DAS & S_3-Foliar spray (FS) of Melatonin 60 ppm @ 30 DAS. Sowing was done on 23 February 2022. VBN (Gg) 2 with the duration of 65 days was used as test variety.

Root nodules plant^{-1}

Five plants uprooted for counting root nodules. The effective nodules plant^{-1} was counted at 45 DAS and the mean value of each plot was worked out and expressed as number of roots nodules plant^{-1}.

SPAD value

Using a SPAD 502 Plus chlorophyll metre, the greenness of the leaves was assessed between 11 AM and 12 PM starting from the second completely expanded physiologically active leaf.

Dry matter production (DMP)

Five plant samples from each treatment plot were collected randomly at harvest. Initially, collected samples were allowed to air dry and kept in oven at 65 ± 5 ºC to obtain a constant weight and expressed in kg ha^{-1}.

Leaf Area Index (LAI)

LAI was calculated using the following formula suggested by Watson (1958).

$$\text{LAI} = \frac{L \times B \times N \times K}{\text{Spacing adopted (cm}^2)}$$

L = Leaf length (cm)
B = Leaf breath (cm)
K = Constant factor (0.6305)

Crop Growth Rate (CGR)

CGR was calculated for the duration of 45-65 DAS as per the formula suggested by Watson (1958) expressed in g^{-2} day^{-1}.

$$\text{CGR} = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weight (g) at time t_1 and t_2 respectively,

P - Spacing in m^2

t_1 and t_2- initial and final day of period of observation

Uptake of nutrients

Total N was estimated by micro kjeldhal method, total P using colorimetric estimation and total K by flame photometer. All three procedures were recommended by Humphries (1956). The uptake of nutrients by plants was calculated by following formula as

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)}}{100} \times \text{dry weight of the plant (kg ha}^{-1})$$

Grain and haulm yield

After harvesting, pods and plants obtained from each net plot area was dried and threshed manually. After winnowing the grains and plants were weighed and calculated to kg ha^{-1}.

Statistical analysis

The data were collected from three replications and statistically analysed by using of analysis of variance (ANOVA) as given by Panse and Sukhatame (1954) for split plot design.

Results and Discussion

Root nodules

Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} recorded significantly more number of root nodules (11.72) at 45 DAS (Figure 1). This might be due to essential nutrient sulphur which is derived from pressmud which increased the root nodule formation (El-Galad *et al.*, 2013). According to Sounda *et al*. (2005) nodule plant^{-1} and nodule dry weight plant^{-1}increased with an increasing amount of calcium applied through gypsum. It was followed by gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} which recorded root nodules of 10.73 plant^{-1}. Lesser root nodules plant^{-1} (6.0) was obtained in Farmers Practice. Among the foliar spray treatments, higher root nodules (9.95) were recorded under foliar spray of BRs 0.2 ppm. Minimum root nodules plant^{-1} (8.03) was observed under foliar spray of CSR GROMOR @ 3%. The interactions were recorded as non-significant.

SPAD value

SPAD meter reading of green gram showed significant difference due to soil amendments and foliar nutrition (Figure 1). At harvest, significantly higher SPAD meter reading was registered in Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} (30.17) over Farmers practice. It was followed by application of Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} which recorded 29.58. Farmers practice registered lower SPAD meter readings (19.72). Among the sub plot, foliar spray of BRs 0.2 ppm produced significantly higher SPAD value (26.34). The increase in chlorophyll content and expression of a regulatory gene involved in the plant defence mechanism may be the cause of the SPAD value increase in BRs treated plants (Lalotra *et al.,* 2017). Lower reading of 25.64 was observed due to foliar spray of CSR GROMOR @ 3%. There was no significant interaction between soil amendments and foliar spray.

Dry matter production (DMP)

As the crop growth stage advanced, there was a progressive and conspicuous increase in the accumulation of root, stem and leaf dry matter. DMP at harvest stage of crop growth was notably influenced by different soil amendments and foliar spray (Figure 1). Gypsum @ 50 % GR + Press mud @ 10 t ha^{-1}produced higher DMP at harvest stage (3270 kg ha^{-1}). This might be due to the extremely soluble and readily available organic matter contributed by press mud which positively altered the soil physio-chemical and biological characteristics (Shafiq *et al.*, 2021). This was followed with the application of Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} registering 3149 kg ha^{-1}. The lesser DMP was noticed in farmers practice (1909 kg ha^{-1}). Among different foliar treatment combinations, foliar spray of BRs 0.2 ppm recorded significantly higher DMP of 2875 kg ha^{-1}. The lowest DMP was computed in foliar spray of CSR GROMOR @ 3%, which registered 2347 kg ha^{-1}. Significant interaction effect was noticed at harvest stage. The higher amount of DMP was recorded in Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm (3425 kg ha^{-1}).

Leaf Area Index (LAI)

The higher LAI of 3.50 was registered with Gypsum

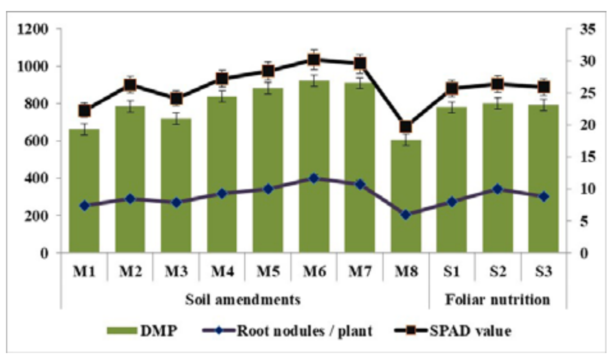

Fig 1. Effect of soil amendments and foliar nutrition on root nodules plant, SPAD value & DMP (kg ha^{-1}) of green gram

@ 50 % GR + Pressmud @ 10 t ha^{-1} (Figure 2). By replacing exchangeable sodium ions at soil colloids with calcium ions from gypsum, sodic soil was improved. This altered the soil environment in the vicinity of the root zone and increased crop development (Rasouli *et al.,* 2013). The next higher LAI was found in Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} with a LAI of 3.30. While the lowest LAI was found in farmers practice which recorded LAI of 2.65. Significantly higher LAI value of 3.32 was noted with foliar spray of BRs 0.2 ppm. Perceptible lower LAI of 2.70 was recorded in foliar spray of CSR GROMOR @ 3%. Combination of soil amendments and foliar spray had measurable interaction effect. At harvest stage, Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}+foliar spray of BRs 0.2 ppm registered 3.87. Reducing sodium toxicity produces less stressful environment for plant growth under gypsum, and a subsequent foliar spray boosted growth metabolism, which resulted in increased LAI (Mondal *et al.,* 2017).

Crop Growth Rate (CGR)

Interaction of phytohormones and nutrients on growth and development of crop plants cause positive responses on crop growth rate (Figure 2). Significantly higher CGR (8.69 g m^{-2} d^{-1}) was recorded with Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}at 45-65 DAS and it was at par with Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} which registered 8.75g m^{-2} d^{-1}. This may due to the effect of combined application of gypsum and pressmud resulting in early root growth and cell division, which causes more additional nutrients to be absorbed from deeper layers of soil, increasing plant growth characteristics and finally increasing CGR. Similar kind of results was reported by Sharma *et al.*(2019). Lesser CGR of 4.90g m^{-2} d^{-1} was recorded under

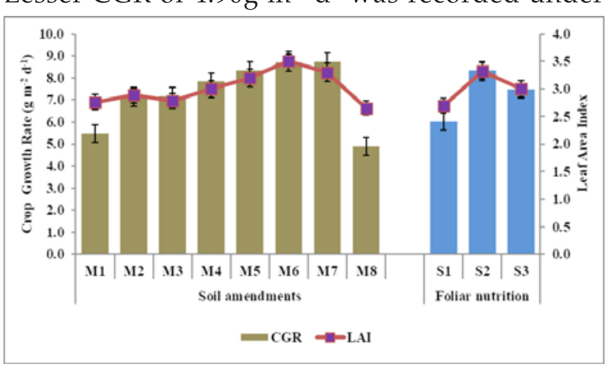

Fig. 2. Effect of soil amendments and foliar nutrition on LAI and CGR (g m^{-2} d^{-1}) of green gram

Farmers practice. FS of BRs 0.2 ppm produced higher CGR (8.35g m^{-2} d^{-1}). Next to this, foliar spray of Melatonin 60 ppm recorded CGR of 7.48g m^{-2} d^{-1}. Whereas, spraying of CSR GROMOR @ 3% recorded lower CGR of 6.02g m^{-2} d^{-1}. Significant interaction was noticed. Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + foliar spray of BRs 0.2 ppm recorded higher CGR of 9.39g m^{-2} d^{-1}. Lesser CGR was observed with farmers practice + foliar spray of CSR GROMOR @ 3% which registered 4.56g m^{-2} d^{-1}.

NPK uptake

Conspicuously, more nutrient uptake was observed with Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} which recorded 56.36, 11.79 and 42.51 kg NPK ha^{-1} at harvest. It was followed by Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} which recorded 53.31, 11.26 and 40.74 kg NPK ha^{-1} (Figure 3). The increased yield and improved uptake of nutrients from the soil may be responsible for the higher uptake values attained with these treatments (Mondal *et al.,* 2017). Whereas, farmers practice registered lesser uptake of 33.62,7.65 and 26.03 kg NPK ha^{-1}.Foliar spray of BRs 0.2 ppm recorded 54.92, 11.58 and 42.29kg NPK ha^{-1}, respectively. The reduced uptake of 38.16, 7.40 and 26.77 kg NPK ha^{-1} were recorded with foliar spray of CSR GROMOR @ 3%. Different soil amendments and foliar spray treatments had considerable interaction atharvest expect P. Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}+ spray of BRs 0.2 ppm registered higher N and K uptake of 60.64 and 45.62 kg ha^{-1}.

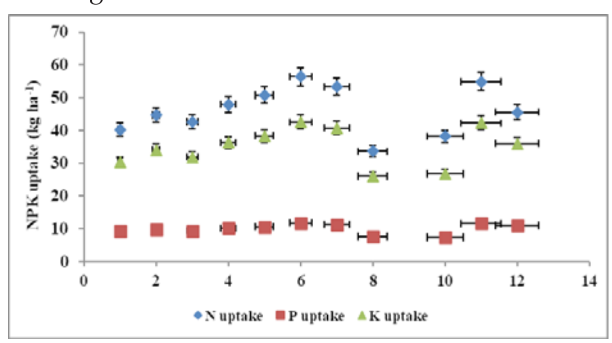

Fig 3. Effect of soil amendments and foliar nutrition on NPK uptake (kg ha^{-1}) of green gram

Grain and haulm yield

Table 1 shows that Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} recorded higher grain and haulm yield of 1043 and 2130 kg ha^{-1}, respectively due to the increased nutrient availability and enhanced soil

Table 2. Effect of soil amendments and foliar nutrition on grain and haulm yield (kg ha^{-1}) of green gram

	Grain yield (kg ha^{-1})					Haulm yield (kg ha^{-1})			
	S_1	S_2	S_3	Mean		S_1	S_2	S_3	Mean
M_1	480	789	685	651	M_1	1611	1799	1620	1677
M_2	559	897	786	747	M_2	1797	1901	1821	1840
M_3	495	811	754	687	M_3	1645	1819	1684	1716
M_4	601	962	816	793	M_4	1845	1982	1869	1899
M_5	655	995	911	854	M_5	1941	2003	1997	1980
M_6	922	1110	1097	1043	M_6	1999	2175	2215	2130
M_7	841	1011	985	946	M_7	1978	2101	2002	2027
M_8	401	655	433	496	M_8	1389	1591	1427	1469
Mean	619	904	808		Mean	1776	1921	1829	
	M	S	M at S	S at M		M	S	M at S	S at M
CD (P=0.05%)	19.46	13.42	36.60	37.97	CD (P=0.05%)	49.37	22.43	71.55	63.46

Main plots: M_1-Pungam GLM, M_2- Pressmud, M_3-CSR GROMOR, M_4-Gypsum, M_5-Gypsum + Pungam GLM, M_6-Gypsum + Pressmud, M_7-Gypsum + CSR GROMOR & M_8-Farmers practice (FP). Sub plots: S_1- FS of CSR GROMOR, S_2-FS of BRs, S_3-FS of Melatonin, CD – Critical Difference @ 5%

properties brought by pressmud and gypsum. Application of gypsum exchanged Na^+ from the soil colloids and lowered the soil pH by adding the required amount of Ca^{2+} to neutralize the soluble HCO_3(Sheoran *et al.*, 2021). These outcomes were confirmed by Sundhari *et al*. (2018). The next higher grain and haulm yield was obtained with Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} which produced 946 and 2027 kg ha^{-1}. Whereas, lower grain and haulm yield of 496 and 1469 kg ha^{-1} was attained with farmers practice. Spray of BRs 0.2 ppm significantly recorded yield of 904 and 1921 kg ha^{-1}. Spray of CSR GROMOR @ 3% significantly resulted in lowest yield of 619 and 1776 kg ha^{-1}. Soil amendments and foliar spraying had significant interaction effect on grain and haulm yield. Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + FS of BRs 0.2 ppm registered higher yield of 1110 and 2175 kg ha^{-1}. Similar result was reported by Daur *et al*. (2013).

Conclusion

In the present study it was found that Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1}+ FS of BRs 0.2 ppm registered significantly higher mean values growth components, NPK uptake, grain and haulm yield over Farmers practice. However, it was statically on par with Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + spray of BRs 0.2 ppm. Hence it was concluded that application of gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + spray of BRs 0.2 ppm @ 30 DAS was found to be a viable option for getting higher yield of green gram under sodic soil condition.

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Authors' Contributions

All authors made substantial contributions to conception and design, acquisition, analysis and interpretation of data and took part in revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability

All data generated and analysed are included within this research article.

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